

We claim:

1. A method for wavefront analysis, comprising:
 - a) acquiring a plurality of wavefront images of light exiting a pupil of an eye, wherein each of the images includes a displaced centroid that is indicative of wavefront measurement information of the eye; and
 - b) calculating and displaying the wavefront measurement information online for a selected aberration order.
2. The method of claim 1, comprising acquiring the images at a rate equal to or greater than 10hz.
3. The method of claim 1 or 2, comprising acquiring at least 50 sequential images.
4. The method of any of claims 1 to 3, further comprising determining an average value and a corresponding standard deviation for the selected aberration order wavefront measurement information.
5. The method of any of claims 1 to 4, wherein step (b) is performed for a selected pupil diameter.
6. The method of any of claims 1 to 5, comprising displaying the average value for the wavefront measurement information for a selected pupil diameter.

7. The method of any of claims 1 to 6, wherein the wavefront measurement information is a manifest refraction value.
8. The method of claim 7, comprising displaying the manifest refraction value online.
9. The method of any of claims 1 to 8, wherein the wavefront measurement information is selected to correspond to one of the second through the 10th Zernike aberration orders or optical equivalents thereof.
10. The method of any of claims 1 to 9, comprising acquiring a corresponding pupil image of the eye for each wavefront image;
determining at least one of position data, size data, shape data, and geometric characterization data of the pupil in each pupil image;
and
displaying at least one of the pupil images and the corresponding pupil image data online.
11. The method of claim 10, comprising displaying a selected wavefront aberration online, selected from a group comprising the second through the 10th Zernike aberration orders or optical equivalents thereof.
12. The method of claim 10 or 11, comprising saving a pupil image and a temporally corresponding wavefront image simultaneously.

13. The method of claim 5, wherein the selected pupil diameter is in a range between about 2mm to 10mm.
14. The method of any of claims 1 to 13, comprising calculating the wavefront measurement information utilizing the algorithm of any of claims 15 to 35.
15. An algorithm for centroid detection in an image, comprising:
 - a) acquiring an $X \times Y$ size image represented by a variable pixel signal intensity;
 - b) compressing the $X \times Y$ size image to an $X/n \times Y/m$ size image, where n, m equal any integers and $X/n, Y/m$ are integer values;
 - c) determining a background intensity for any position in the compressed image and subtracting this background from the compressed image;
 - d) detecting a plurality of approximately positioned centroids in the background-subtracted compressed image;
 - e) iterating step (d) until approximate positions of a desired plurality of centroids are detected;
 - f) converting the approximate position of the desired plurality of centroids into more exact positions in the $X \times Y$ size image, whereby every centroid position in the image has been identified.

16. The algorithm of claim 15, comprising:
 - g) iterating step (f) until a desired level of more exact positions is determined.
17. The algorithm of claim 16, further comprising:
 - assigning a quality factor to each centroid in relation to a magnitude of positional change for each centroid in each iteration of step (g).
18. The algorithm of any of claims 15 to 17, comprising:
 - sorting the centroids determined from step (f) according to a predetermined configuration.
19. The algorithm of claim 18, wherein the configuration is a geometric grid.
20. The algorithm of claim 19, comprising a rectangular grid.
21. The algorithm of claim 18, wherein the configuration is a ring.
22. The algorithm of claim 18, wherein the configuration is a straight line.
23. The algorithm of claim 18, comprising:
 - associating each determined centroid with a respective centroid image forming element.
24. The algorithm of any of claims 15 to 23, wherein compressing the $X \times Y$ size image to an $X/n \times Y/m$ size image comprises:

a) averaging the signal for every pixel in an $n \times m$ square starting in a first predetermined region of the original image and scanning through the image, setting a signal level in a corresponding first predetermined region of the compressed image to the average value of the first predetermined region;

b) repeating step (a) for a second and subsequent predetermined regions until the $X/n \times Y/m$ image size is obtained.

25. The algorithm of claim 24, wherein $n = m = 8$.

26. The algorithm of claim 24 or 25, wherein the first predetermined region is the upper left corner of the image.

27. The algorithm of any of claims 15 to 26, wherein step (c) comprises:

dividing the compressed image into a plurality of image segments each of which contains a plurality of centroids, determining an average signal value for each image segment, and extrapolating the average values for each image segment to determine the background intensity level.

28. The algorithm of claim 27, wherein the image segments are squares.

29. The algorithm of claim 27, wherein each image segment contains approximately 3 to 5 centroids.

30. The algorithm of any of claims 15 to 29, wherein step (d) comprises:

- a) determining a maximum signal value in the image;
- b) setting a threshold value as a predetermined percentage of the maximum;
- c) determining an X-position, a Y-position, and a signal strength of each pixel that has a signal strength greater than the threshold value;
- d) sorting the values from step (c) in descending order of signal strength;
- e) assigning the highest signal strength as first approximately positioned centroid; and
- f) selecting a pre-set condition for defining all sorted values as approximately positioned centroids, which obey the pre-set condition.

31. The algorithm of claim 30, wherein the pre-set condition is that the position of each subsequent approximately positioned centroid is a farther distance away than a pre-set distance from all yet determined approximately positioned centroids.

32. The algorithm of claim 30 or 31, further comprising setting a new threshold value to a predetermined percentage of a minimum value of the sorted signal strengths and iterating steps (c-f), wherein

the already identified approximately positioned centroids are not identified again.

33. The algorithm of any of claims 15 to 32, wherein step (f) comprises:

defining a boundary structure around every approximate position of the desired plurality of centroids in the original image; and
determining a center of mass of the signal for the signal distribution inside of the boundary.

34. The algorithm of claim 20, comprising:

a) calculating a straight line formula for each sorted centroid, i , containing the centroid point, i , and having a slope between the values of about <-0.1 or >0.1 ;

b) calculating a distance, n_i , between the line and a reference position in the image;

c) sorting all centroids, i_n , by n_i starting with the smallest n_i value;

d) assigning the centroid with the smallest n_i to a first row and storing this centroid as a last centroid in the first row;

e) defining a region as an area to the right of a last centroid of a given row having dimensions that are variably controllable by an

imaging component parameter and a shape suitable for detection of a selected grid structure;

f) obtaining the next n_i value and determining, for all existing rows, whether the centroid is within the region;

g) assigning the centroid as the last centroid in the given row if the centroid is within the region, or, assigning the centroid as the last centroid in a new row if the centroid is outside the region;

h) repeating steps (f-g) for all centroids;

i) calculating an average y-position for each row and sorting the rows according to the average y-positions to identify a top row, Row 1, a next row, Row 2, and so on to Row n ;

j) assigning the centroid with the smallest n_i to a first column and storing this centroid as a last centroid in the first column;

k) defining a region as an area below the last centroid of a given column having dimensions that are variably controllable by the imaging component parameter and a shape suitable for detection of the selected grid structure;

l) obtaining the next n_i value and determining, for all existing columns, whether the centroid is within the region;

m) assigning the centroid as the last centroid in the given column if the centroid is within the region, or, assigning the centroid

as the last centroid in a new column if the centroid is outside the region;

n) repeating steps (l-m) for all centroids; and

o) calculating an average x-position for each column and sorting the columns according to the average x-positions to identify a first column, Column 1, a next column, Column 2, and so on to Column n.

35. The algorithm of claim 34 wherein the reference position is an upper left corner of the image.

36. A device readable medium having stored thereon an executable instruction in the form of the algorithm of claim 15.

37. A wavefront measuring apparatus, comprising:

an illumination component adapted to deliver a small spot of light onto a retina;

an imaging component that can form a centroid image of illumination light scattered from the retina and exiting a pupil of an eye;

a detector adapted to acquire the centroid image;

a processor in operative connection with the detector that can execute a centroid displacement calculation to determine wavefront measurement information;

a display component in operative connection with the processor
that can display a selected wavefront measurement information; and
means for instructing an online calculation and display of the
selected wavefront measurement information.